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Application of Advanced Surveying Techniques in Solving Traffic Problems

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Abstract— transportation networks represent an important issue for all residences and visitors in any city. Therefore, traffic congestion is a major problem that affects greatly the mobility of personals and vehicles. Then, a rapid emergency response should be always available, especially in case of accidents and/or fires to ease the transfer of injured to any medical services. In this context, geographic information systems (GIS) became an essential and effective tool in specifying the shortest path between any two locations within the network.
This paper addresses the application of GIS in computing the shortest path between a source and a destination location with a certain part within the greater Cairo, Egypt. In addition, the network was monitored in different periods of year, in order to investigate the change in the shortest path along with its corresponding travel time due to the variation of the traffic volume. The selected network consists of 42 segments, varying in length, width, orientation, and classification. The results show the powerful of GIS in this field of transportation network, besides its ability to overcome some drawbacks inherit with in the commercial Google Map interface when compared together. The collected real data proved that the corresponding Google Map reported time has accuracy of nearly 70%.

Index Terms: Geographic Information System in Transportation (GIS-T), Transportation Network, Shortest Path, Google Map Navigation.

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1 INTRODUCTION

A transportation network system represents one of the most development stages of any country. This is due to the fact that road can be considered as the key channels in a modern society's substructure, lending a great deal to the allocation of goods, funds and individuals [Ref]. Hence, highly developed countries are facing major problems in transportation management that need lots of money and effort to be solved. Among them, the growing traffic congestion in urban areas which requires a conscious network planning concerning roads classification and setting speed limits to match road function [1].

Accordingly, routing of the large amount of vehicles and/or personnel in complex logistics systems is a task to be critically solved in numeric applications, such as detailed models of transportation network or peak crowded seasons. This will be very useful, as an example, in a rapid emergency response to the scene of a traffic accidents and transportation of the injured people to a medical facility for saving lives. Accordingly, a best route of least resistance between two or more points should be rapidly specified within the network. This route should take into account connectivity among all network segments and travel restrictions such as one way streets and rush-hour traffic [2].

In this context, Geographic Information System (GIS) is becoming more widely used in transportation planning agencies, especially among metropolitan transportation organizations. In many developed countries, highway maintenance management is becoming a critical issue. Many more authorities are now able to use GIS for Highways and transport management, due to falling costs and its increasing abilities over friendliness. GIS offers the transport planners a medium for storing and analyzing data on population densities, land uses, travel behavior, etc. Moreover, the application of GIS to a diverse of problems in transportation networks is now well-established and always is undergoing recent developments. It is a powerful tool for the analysis of both spatial and attributes data and for solving of important problems in networking [3].

This paper addresses the use of GIS capabilities in the design of a certain transportation network. In this context, a tested study area consists of many consists of many classified road segments are considered and processed. Hence, the main objectives of the current research are summarized as follows:

- Producing a shortest path map for all roads within the case study area using ArcGIS software.
- Comparing between the available allowable speed and the estimated speed on each road segment.
- Determining the extent of deterioration on the road network throughout the year from a season to another.
- Validating the Google map application in the study area during the same different tested seasons.

- Finding a certain formula between Google map time and real time during these seasons.

2 ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN TRANSPORTATION NETWORKS

A network is a system of linear features that has the appropriate attributes for the flow of objects. A road system is a familiar network. Other networks include railways, public transit lines, bicycles paths, water network, and streams. A network is typically topology–based: lines (arcs) meet at intersections (nodes or junctions), lines cannot have gaps, and lines have directions. Each components of the network along with the corresponding topology among them must be clearly identified by defining the links, defining the intersection points between those links and determining the current state of each link, whether it allows traffic in one direction or two directions or even closed streets. A network with the appropriate attributes can be used for a variety of applications. As, path finding and accessibility measures will be discussed. It also links a network to solving location-allocation problems and transportation planning modeling. Some applications are directly accessible through commands in any GIS commercial software package [4].

This network vector data model has undergone more changes over the past two decades than any other aspect of GIS [5]. Spatial analysis tools that make GIS unique and powerful compared with the other data analysis systems. These tools associated to ask questions using spatial and non-spatial data models to solve existing problems. In addition, shortest path is one of the most GIS network applications which find the path with the minimum cumulative impedance between nodes on a network. The path may connect just two nodes-an origin and a destination-or have specific stops between the nodes. Shortest path analysis can help a driver plan routine trips between home and workplace or can be used in an emergency service connect a dispatch station, accident location and hospital, etc [6]. Depending on the type of cost, the shortest path can be referred to as the shortest, fastest or most optimal path [7]. Also, the role of GIS was not only to find the shortest path between two points, depending on the distance or even time but the role of GIS is extent to link the shortest path with the most safety path through developing a new travel cost function in the route selection process that integrates the crash cost estimation with the travel time cost in a comprehensive routing system [8].

3 METHODOLOGY OF RESEARCH

After the emergence of geographic information systems with its corresponding various analysis programs and software analysis supported by geographic information system give better results in the design of networks, it became so easy to determine the path between two points. On the contrary, it has become common practice to define specific paths for drivers to pass on several specific points. Also, the preferable positions of the first ambulance or even the fire water pumps can be easily located on the network so that they are in the nearest place and in the shortest possible time to reach the users.

2.1 Identifying Assessment Criteria

Different assessment criteria are taken into consideration for implementing the pre-mentioned methodology of investigation. In this context, the final path will be selected according to the least time measured between both origin and destination. This time is the accumulated measured ones related to each segment that constitute the required path.

In addition, another criterion is considered within all segments of the network. In this context and with the collected data, the actual speed run on each segment can be easily calculated. Hence, these speeds will be compared with the allowable limited ones related to each road classification, as arterials, collectors and locals. This will be useful in specifying the segments that cause a delay in the travel time. Accordingly, the reason for that delay whatever traffic signal, road maintenance, road quality, etc, will be updated to reach at the best possible time.

2.2 Study Area Description

The study area is located in Cairo city lying between latitudes of 30.068°N and 30.119°N; longitudes of 31.285° E and 31.353° E, in the Northeast region of Cairo. It extends from Elhejaz square in Heliopolis distinct which considered the origin point to El-Abbassia distinct which considered the destination point. A large number of links leading the transfer from origin to destination using two main roads Salah Salem and elhejaz-elkhalifa elmamoon can be considered besides a large number of links that allow the exchange of trip between them. The study area consists of about 42 small segments, ranging from 100 meters to 1,200 meters, and covers an area about 9.3 km^2 as shown in fig.(1).

In this network, all classified roads along with their allowable limited speeds are existed.

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Figure1. The study area location

4 THE USED DATA

To achieve the objective of the current research, different applications were used to collect the needed data. These applications will be discussed in details in the following sub-sections.

4.1 Androsensor

Androsensor is a free application available on all smart phones whose idea is simply a continuous tracking of the mobile device while moving. This program assigns the following; the accelerometer, magnitude field, and orientation in each x, y, and z directions, light, proximity, location latitude, location longitude, location altitude, speed, and time. For each segment, the corresponding geographic coordinates is listed. These coordinates can be used to produce a map of the network by connecting them together through the starting and ending points of each segment as shown in figure (2). This output map can be verified and compared with a corresponding available base map for the same study area. The base map is surveyed by ground surveying technique using a Topcon GT-702 total station, through two control points. Of course, the surveyed data concerns only with all roads and intersections.

The network was monitored over a whole year as a result of changing traffic volumes from season to season. The year is divided into three different seasons: The first season represents the summer, which is the average season in terms of traffic as a result of the holiday season; the second season represents the academic year, which represents a congested season in terms of traffic movement; the third season represents the holly month of Ramadan, where the traffic is simple due to the association of Egyptians with religious rituals in this blessed month. This diversity in traffic volumes had a direct effect on the shortest path between the starting and ending points or even on the travel time and cost estimation.

The study was conducted for 3 weeks in both the summer holiday season and the academic year, and the network was studied for one week in the month of Ramadan. The dates of these weeks were as listed in Table 1 in order to monitor the extent of all criteria change. For each week, the monitoring was carried out in just five days, on Friday, Sunday, Tuesday, Wednesday and Thursday.

To study the traffic variation in one day regardless the weekly change or even the seasonal change, the network was monitored twice daily. The first is the morning peak nearly 8:00 am, and the other is the evening peak nearly 3:00 pm, in the summer and the academic seasons. Monitoring hours were changed to match the morning and evening peak times, with monitoring nearly 9:00 am and 8:00 pm respectively in holly Ramadan.

Table 1
The time schedule

Week	From	To	Season
One	7/7/2017	13/7/2017	Summer holiday
Two	14/7/2017	20/7/2017	Summer holiday
Three	21/7/2017	27/7/2017	Summer holiday
Four	15/9/2017	21/9/2017	Academic year
Five	22/9/2017	28/9/2017	Academic year
Six	3/11/2017	9/11/2017	Academic year
Seven	2/6/2017	8/6/2017	Holly Ramadan

4.2 Google Earth Pro

Google Earth pro was used to take a high-quality image with resolution (4800*2602) of the study area to match the tracking path taken by Androsensor application. The roads are currently available for the latest version of Google Images on February 2017 which taken by TM satellites with resolution 20*20m for one pixel. Egypt and Cairo in particular, the horizontal positional accuracy of online Google earth imagery gives almost RMS error of about 10.0 m which can be minimized until 2.0 m by enhancement the online imagery and registration.

Geometric transformation is the process of using a set of control points and transformation equations to register a digitized map, a satellite image, or an aerial photograph onto a projected coordinate system. Geometric transformation is a common operation in GIS, remote sensing, and photogrammetry this is called in GIS the georeferencing. The GIS packages allow different transformation methods such as equiarea, Similarity, affine, projective transformation. The general rules suggest the use of affine transformation for image-to-map transformations and the projective transformation for aerial photogrammetry [9].

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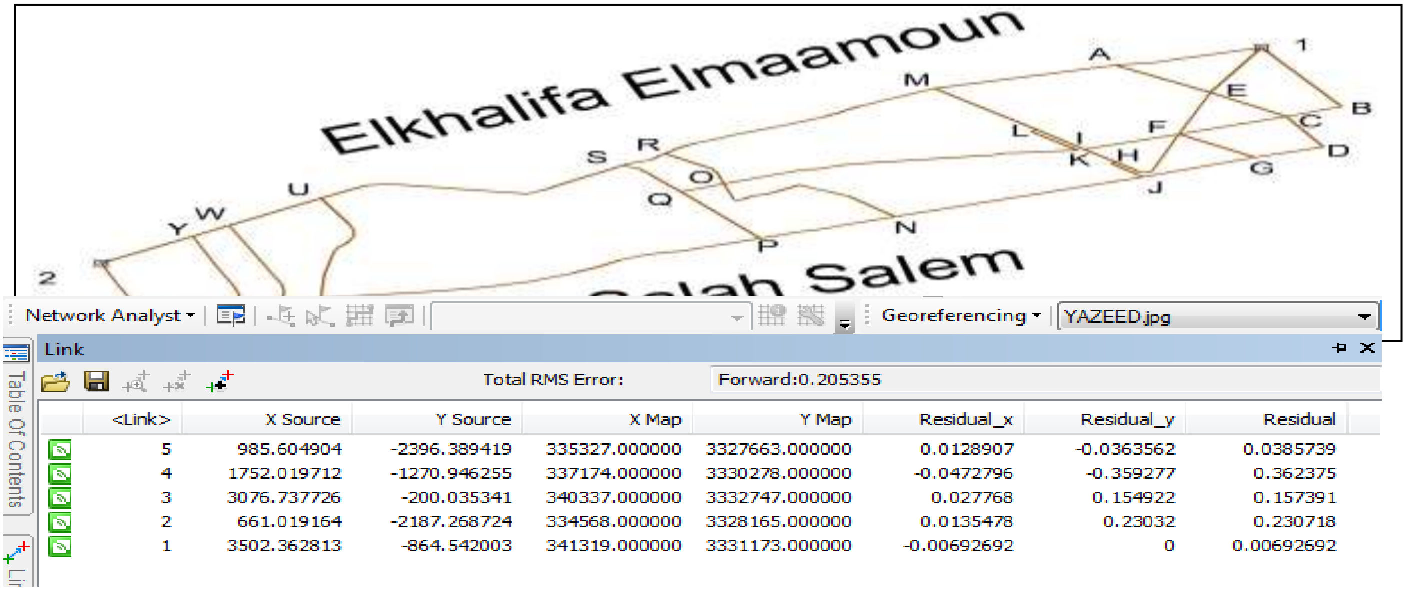

<Link>	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
5	985.604904	-2396.389419	335327.000000	3327663.000000	0.0128907	-0.0363562	0.0385739
4	1752.019712	-1270.946255	337174.000000	3330278.000000	-0.0472796	-0.359277	0.362375
3	3076.737726	-200.035341	340337.000000	3332747.000000	0.027768	0.154922	0.157391
2	661.019164	-2187.268724	334568.000000	3328165.000000	0.0135478	0.23032	0.230718
1	3502.362813	-864.542003	341319.000000	3331173.000000	-0.00692692	0	0.00692692

Figure3. The coordinates of control points and its root mean square error

Figure (3) shows the used five control points for georeferncing the tested study area image along with their coordinates and it's corresponding RMS error. Where (X source, Y source) refers to the ArcGIS software coordinates and (X map, Y map) indicate to the online Google earth coordinates in meters. So, the residual in both X and Y direction measures in meters. Only three points are used as common points to calculate the required 6 transformation parameters, where as the remaining two points can used to improve the quality of the transformation process.

It can be easily conducted that, the root mean square error is about 20.5 cm which is lower than the acceptance value which is compared by the minimum value between 6 m or one pixel for the study area [9].Google earth imagery has nearly a systematic positional shift. But, in general, Google earth represents a powerful and attractive source of positional data that can be used for investigation and preliminary studies with suitable accuracy and low cost. In addition, there is no significant difference in lengths between the high accuracy map and Google earth due to the shift in point coordinates makes a parallel line for the original one [10].

4.3 Google Map

The Google Map application was used to determine the expected travel time of the total trip from El-Hejaz square to El-Abbassia for all the days mentioned in all the specified times. Google Map performs continuous tracking to GPS locators (systems) in mobile phones where the coordinates of the mobiles could be Determined and by changing that coordinates with time. The application will determine the fastest route between two points without considering whether this path is the longest or not with an indication of the traffic condition on the selected road through several colors as seen in figure 4.

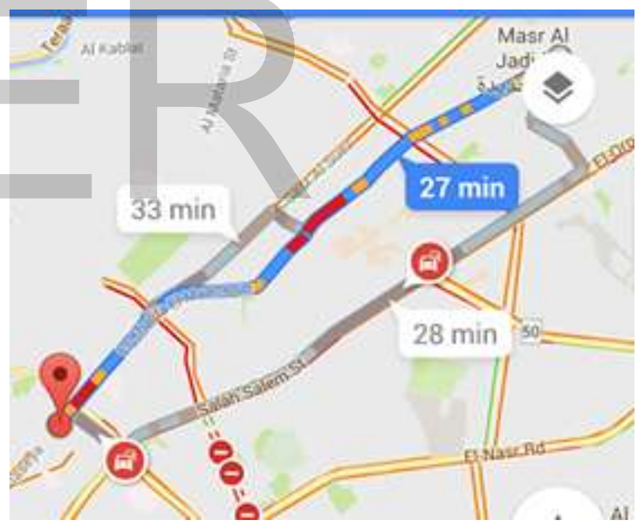

Figure4. Google map fastest route

5 RESULTS

Several comparisons will be carried out to find the extent of change between the three seasons regarding the volume of traffic on the quality of the network and the average Speeds. Moreover, the shortest paths between both real collected data and Google map can be compared. Of course, this will be upon the computed real time and the corresponding reported one.

5.1 Real Time between Different Seasons

In this comparison, the change in the computed value of time for the corresponding output shortest path will

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be compared at both monitoring time among the three seasons. Accordingly, this comparison will depend on the average time value computed at each day in both morning and evening period. Table 2 shows the variation of the travel time between summer holidays, academic year, and Ramadan.

Table 2
The real time solutions in seconds according to different seasons

day	period	Summer	Academic	Ramadan
Friday	Morning	499	495	490
	Evening	543	546	552
Sunday	Morning	568	596	537
	Evening	657	689	617
Tuesday	Morning	861	982	641
	Evening	1030	1137	807
Wednesday	Morning	966	1124	676
	Evening	1164	1240	857
Thursday	Morning	1187	1389	745
	Evening	1387	1557	918

The above table indicates that there is no significant change in trip time between the three seasons during the first days of the week, which nearly represents the off days. Also, the change increases during the second half of the week, where Ramadan is the least time for the trip compared to the summer and the academic semester which represents the biggest deterioration Network. Finally, the academic season always gives the most delay time for the trip.

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5.2 Shortest Path

Depending on the observation time the shortest path between the two points was varied. The Arc GIS commercial software was used to solve the network during all observed days. As a result, four solutions were found throughout these observations and were randomly repeated during the study seasons. The solutions were as follows from Figure 9 to Figure 12.

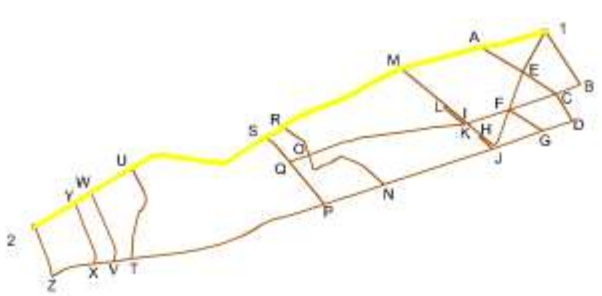

Figure5. Solution one

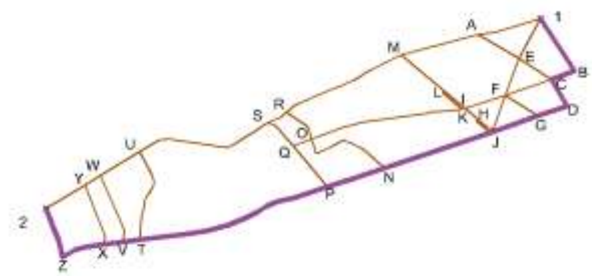

Figure6. Solution two

Figure7. Solution three

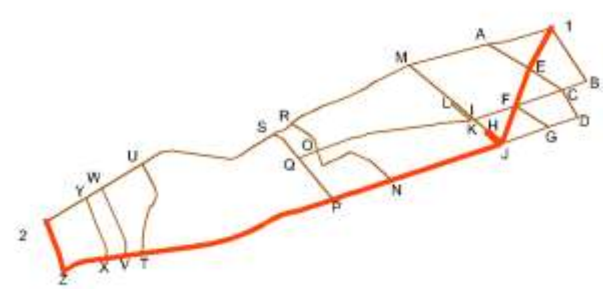

Figure8. Solution four

Table 3 shows the frequency of these solutions for weekdays for each season and to explain the change in solutions due to changing in traffic volume from one season to another and impact on the choice of the shortest path between the two points.

Table 3
Shortest path solutions

Day	Summer	Academic year	Ramadan
Friday	***One***	***One***	***One***
	One	***One***	***One***
Sunday	***One***	***One***	***One***
	One	***One***	***One***
Tuesday	***Two***	***Two***	***One***
	Two	***Two***	***Two***
Wednesday	***One***	***Three***	***One***
	Two	***One***	***Two***
Thursday	***Two***	***Two***	***One***
	Four	***Two***	***Two***

5.3 Network Quality

The network cannot be fully evaluated depending on the computed average speed on all different segments. This is because of each segment has its own limited allowable speed specified by the general authority for traffic. Then, segment quality is calculated as (observed average speed*100/ maximum allowed speed)

The average speed was calculated on each segment in all days mentioned before during the three seasons and through which the segment quality was calculated for 42 segments separately. Table (4), table (5), and table (6) list the statistical parameters of the network quality in each season, respectively

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Table 4
The statistical parameters of the network quality in the summer holiday (Morning peak)

	Friday	Sunday	Tuesday	Wednesday	Thursday
Mean	**89.69**	**77.78**	**58.61**	**58.91**	**49.39**
Max	**100**	**95.22**	**86.73**	**86.15**	**78.80**
Min	**57.75**	**49.32**	**20.62**	**17.01**	**18.38**
RMS	**9.04**	**11.26**	**14.87**	**15.96**	**14.99**

Table 5
The statistical parameters of the network quality in the academic year (Morning peak)

	Friday	Sunday	Tuesday	Wednesday	Thursday
Mean	**89.19**	**75.33**	**55.09**	**52.08**	**43.49**
Max	**99.76**	**92.93**	**77.78**	**72.47**	**66.24**
Min	**58.1**	**48.14**	**17.31**	**16.29**	**13.07**
RMS	**8.12**	**11.19**	**14.68**	**13.5**	**12.76**

Table 6
The statistical parameters of the network quality in the Ramadan (Morning peak)

	Friday	Sunday	Tuesday	Wednesday	Thursday
Mean	**93.58**	**86.41**	**74**	**71.26**	**65.43**
Max	**100**	**96.13**	**90.13**	**87.85**	**82.98**
Min	**77.14**	**62.86**	**45.97**	**45.81**	**41.85**
RMS	**5.33**	**6.81**	**10.32**	**9.63**	**8.93**

The same concept is repeated again for the evening period, in order to assess the network status and service. Consequently, figure (9) and (10) show the difference in network quality in the three seasons at all weekdays, related to the first and second trip, respectively.

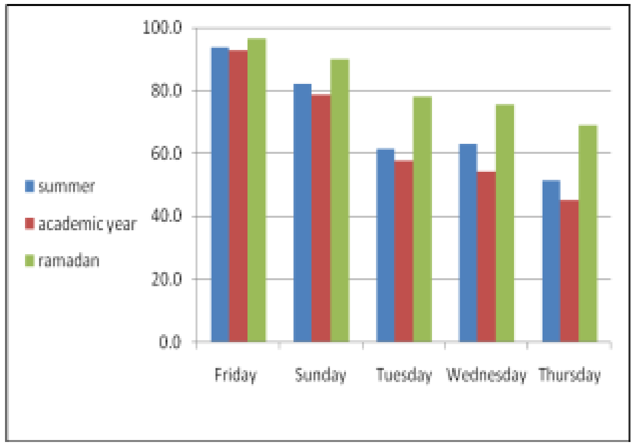

Figure9. The variation of the network quality during morning trip

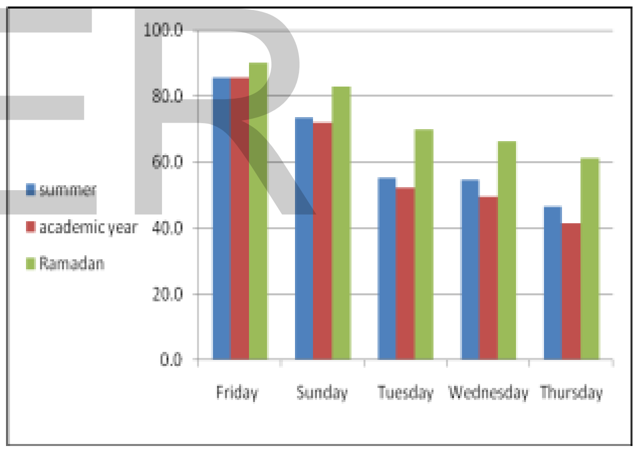

Figure10.The variation of the network quality during evening trip

From the previous figures, there are no significant differences between the quality of the network in both the summer and academic year, where the biggest difference occurred in Ramadan. In other words, the high performance of the network occurs in Ramadan at both observed trips.

5.4 Google Map Evaluation

With the advent of data collection and processing it became possible to analyze these data on the spot. One of the main applications that being used widely nowadays is the Google map, to be applied in the field of transportation networks assessment and services. In this context, the shortest path between any two origin and destination locations within a certain network can be easily specified, along with its corresponding travel time. Recently, it also marks the congestion parts at any segment of the network to be avoided.

As stated before, geographic information system (GIS) with its powerful capabilities and commercial software play an essential role in the same field. According the selected network that being monitored by the real collected data will be analyzed again by Google map application at same seasons and weekday. This will be carried out in order to asses and validate the Google compared with real data, which is one of the main objectives of current paper. The comparison includes the shortest path and the corresponding travel time, which helps in the evaluated of the Google map in its correctness of the reported travel time between any two locations. The related output results are shown in figure (11), figure (12), figure (13), corresponding to the three investigated seasons respectively.

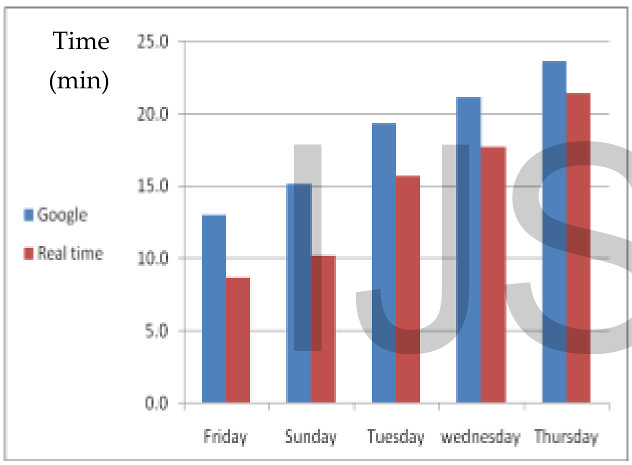

Fig.11.The travel time reported from both Google Map and Real data in summer holiday

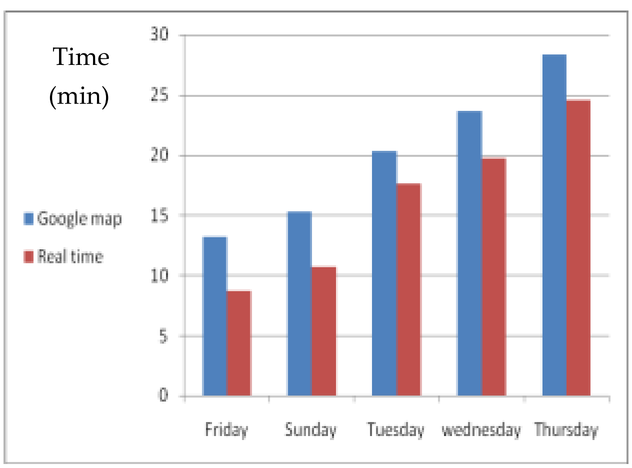

Fig.12.The travel time reported from both Google Map and Real data in Academic season

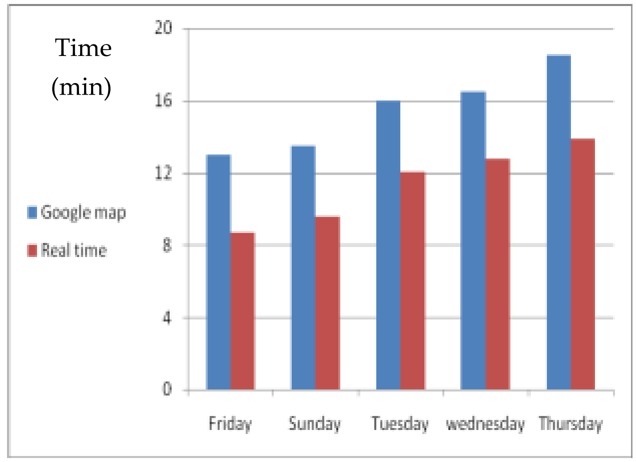

Fig.13.The travel time reported from both Google Map and Real data in Holly Ramadan

All above figures reveal that there is a significant difference in the travel time between both Google Map application and the collected real data. These differences range between 2.2 min and 5.0 min in all investigated seasons. The minimum variation in the reported time usually occurs on Sunday where as the corresponding maximum variation happens on Thursday in addition, the actual shortest path derived from both sources is nearly the same with a percentage of alteration not exceed 10% of all tested study cases, that including the monitoring weekday in the three selected seasons.

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6 Conclusion

Finding optimal path or shortest path between two specified points is one of the classical and fundamental problems in transportation network analysis. Accordingly, based on the obtained results as well as their analysis, it can be concluded that:

- There is no significant difference in the output shortest path solution between both Google map and real data in the selected transportation network. Both methods give the same solution in 64 times from 70 observations with nearly 90% matching.

- Google Map reports travel time greater than the corresponding one collected from the real data. The difference ranges from 2.2 min in the peak days to 5.0 min in the off peak days.

- The network quality, which indicates the substation of actual vehicle speed within the allowable limited one at all segments, suffer deterioration from off days to work days. Briefly, the network quality has its maximum value of nearly 90% on Friday and its minimum value of nearly 45% on Thursday. Keeping in mind that, Ramadan is the best season at investigated periods to range between 65% and 94.

- In order to acquire a precise and comparable data using Androsensor, the vehicle speed should not exceed 20 km/hr. In this case the error in the computed coordinates and hence the segment length will be limited. This is an important issue to avoid a wrong reported travel time, which finally affect the correctness of the output shortest path.
- Generally for the tested study area, khalifa el Maamoun will be the preferable road that connecting both origin and destination locations on off peak days (Friday to Sunday), whereas Salah Salem road will be the alternative one on peak days (rest of the week).

Finally, it is recommended to gather a big volume of data with the same adopted terminology. In other words, the collected data can be monitored many times with day at all possible seasons. Accordingly, certain formula can be predicted between the reported Google Map travel time and the corresponding actual one.

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